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OPTIMIZATION OF SOLID WASTE VALORIZATION IN ALGERIA: CHALLENGES AND SUSTAINABLE SOLUTIONS

Abstract: This study assesses solid waste management in Algeria, highlighting challenges related to production, management, and recovery. The objective is to identify system deficiencies and propose sustainable solutions to reduce environmental and health impacts. A mixed approach was adopted, combining official data, field surveys, and academic research. The results show fluctuating waste production trends. Between 1994 and 2016, waste volume tripled, reaching 12 million tons per year due to population growth and improved living conditions. However, the post-COVID-19 period (2019-2023) recorded a decline in household waste due to behavioral changes. At the same time, plastic waste has increased, although organic waste remains predominant. Major cities such as Algiers and Oran generate the most waste, while rural areas suffer from insufficient collection services. Despite improvements in urban waste collection coverage, 82% of waste is still disposed of in overcrowded landfill centers or illegal dumps, with recycling efforts remaining marginal despite initiatives like PROGDEM and Eco-Jem. Modernizing infrastructure, improving selective waste sorting, and strengthening recycling efforts are necessary. Integrating circular economy principles and adopting advanced technologies, such as composting and optimized recycling, are essential for sustainable waste management in Algeria.

Keywords: waste management, Geographic Information Systems (GIS), waste valorization, sustainable development, environmental pollution

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Introduction

One of the major challenges the world faces today is environmental management, particularly waste management. The issue of waste is ever-present, affecting individuals both professionally and socially. Major treatment methods such as recycling, landfilling, incineration, and composting provide diverse solutions, yet their implementation remains complex (Manea et al., 2024). This complexity arises from the interplay of economic, technical, social, and environmental factors, often shaped by political and cultural contexts.

Since the 20th century, the global population has experienced rapid growth, rising from approximately 5.9 billion in 1997 to 7.3 billion in 2015 (Gelbard et al., 1999).This demographic expansion, coupled with industrialization, has led to massive waste production. The initial information regarding global waste production requires adjustments to reflect the most recent data. According to the Global Waste Management Outlook 2024 report by the United Nations Environment Programme, global municipal solid waste production was estimated at 2.3 billion tons in 2023, with projections reaching 3.8 billion tons by 2050 (UNEP, 2024). Every day, human activity generates more than 10 billion kilograms of waste, highlighting an alarming situation.

In the Maghreb region, particularly in capitals such as Algiers, Tunis, and Rabat, waste production has continuously increased since the 1960s. This rise could reach 100 to 300% of the initial production by 2020 (Beyene & Kotosz, 2021). These countries, engaged in development dynamics aimed at improving the quality of life and the future of their populations, are facing the harmful consequences of waste on public health, the environment, and overall quality of life. Municipal solid waste management has become a central issue in their development strategies, with a growing awareness of the need for a more rational and sustainable approach.

In 2023, Algeria had an estimated population of approximately 46.34 million, according to the ONS (ONS, 2023). The management of municipal solid waste continues to be a major challenge for the country. In 2022, the Province of Algiers recorded the collection of more than 672,000 tons of municipal and similar waste (Hachemi et al., 2025), which is equivalent to an average of over 1,841 tons per day, according to APS (Agence Presse Service). This data indicates that more recent waste generation volumes are available, highlighting the need to reconsider data from 2016. Given the potential changes in the structure and volume of waste generation over the nine-year period, the main recommendation of this paper is to update and adapt waste management strategies accordingly.

To address these challenges, several initiatives have been launched. For example, the Centre for Environmental Research (CRE) organized workshops in February 2023 focused on municipal waste management and its integration into a circular economy.

Beyond environmental preservation, waste management also represents an economic opportunity (Allen, 2023). Waste recovery through recycling and reuse is a priority for the Algerian authorities. Programs such as the National Program for Integrated Household Waste Management (PROGDEM) and the National Program for Industrial and Special Waste Management (PNAGDES) reflect this commitment. These initiatives aim to harness available resources while encouraging the creation of businesses and investment in activities related to recovery and recycling (CNTPP, 2014).

However, despite these efforts, waste production continues to increase every year. Illegal dumpsites are proliferating, causing harmful effects on the environment, public

health, and quality of life. The rate of waste generation far exceeds the capacity of infrastructure to manage it. Furthermore, the insufficiency and inefficiency of current waste treatment systems, including landfilling, worsen the risks for populations and ecosystems.

Faced with this situation, a proactive waste management approach is essential, particularly through simple actions such as sorting. This eco-citizen initiative aims to integrate waste into a virtuous cycle, enabling its recovery while reducing the amounts to be stored.

The issue raised is: How can waste management in Algeria be optimized to meet environmental standards and promote sustainable development while minimizing negative impacts on public health and the ecosystem?

This research primarily aims to obtain detailed technical data on the current state of waste management in Algeria in order to assess existing practices and identify potential gaps. It also seeks to optimize technical information related to the recovery of solid waste, highlighting the most suitable solutions for sustainable and effective waste management development.

Material and Methods

This study adopts a mixed approach combining quantitative and qualitative analyses to assess solid waste management in Algeria and its environmental impact.

Data Collection

The data used in this research comes from several sources. First, official reports and government studies on waste management in Algeria are utilized. Next, surveys and field observations are conducted with local authorities. Additionally, statistical data from organizations specialized in waste management and environmental issues are analyzed. Finally, scientific articles and academic works on waste management strategies and waste recovery complement this data collection.

Data Analysis

The analysis relies on several methods. A descriptive analysis is conducted to assess trends in waste production and treatment in Algeria, with particular attention to recycling and disposal methods. In addition, semi-structured interviews are conducted with key stakeholders in the sector to gather opinions on the challenges and opportunities related to waste management. Furthermore, the use of GIS (Geographic Information System) data plays a central role in this analysis. These tools allow for the mapping of waste distribution and evolution, spatial analysis of waste management infrastructures (sorting centers, landfills, recycling units), and the evaluation of environmental impacts by overlaying data on pollution and waste density.

This methodology enables a comprehensive understanding of waste management dynamics and the measures needed to improve their efficiency and sustainability in Algeria.

Results and Discussion

Urban solid waste results from household consumption, public institutions (schools, hospitals, etc.), commercial establishments, and businesses. In developing countries, the quantities of waste produced vary from one city to another, depending on several factors, the most crucial being population growth. Indeed, the total quantities of household and similar waste collected by the public service provide a better understanding of waste trends, as illustrated in the following table:

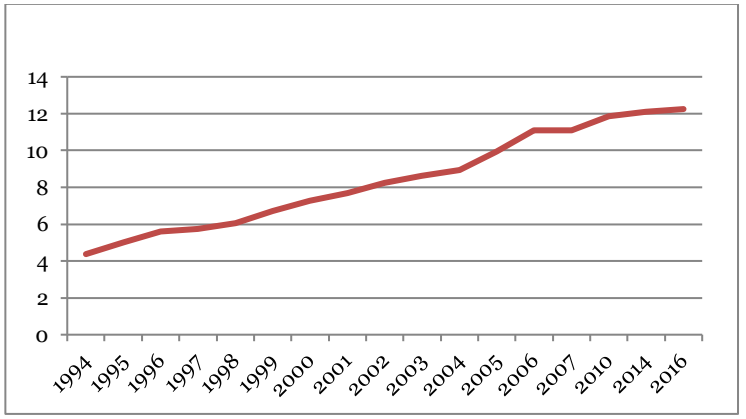


Fig. 1. Evolution of household waste during (1994-2016) (Source: AND, 2019)

We observe a significant increase in the amount of waste collected since 1994, starting with a production of 4 million tons per year, which continued to rise in 2000, reaching 7 million tons per year, and eventually reached 12 million tons per year in 2016.

These figures can largely be explained by a relatively strong population growth on the one hand, and on the other hand, by improvements in the quality of life. Additionally, there is the behavioral factor, characterized by the general shift of Algerian society towards a consumer society, with the integration of Algeria into the market economy.

According to a study by the National Waste Agency (AND), household and similar waste (DMA) production in Algeria saw a significant decline between 2019 and 2021. In 2019, the amount of DMA was estimated at 12.6 million tons, with an average of 0.8 kg of waste generated per person per day. By 2021, this amount had decreased by 12%, reaching 11.1 million tons, with an average of 0.68 kg per person per day (AND, 2020; Algerie Press Service, 2022).

This reduction of more than one million tons of waste between 2019 and 2021 can be attributed to the COVID-19 pandemic, which led citizens to rationalize their consumption, thereby reducing waste production. This trend aligns with the National Strategy for Integrated Waste Management (SNGID) by 2035, which recommends not exceeding an average of one kilogram of waste per person per day (ECO, 2022).

Finally, it is important to note the loss of technocultural systems that were concerned with the environment, due to the gradual dominance of individualism and the disregard for public goods - in other words, the deterioration of mentalities and the lack of civic responsibility among citizens.

Waste Production and Population Report

The quantities of waste produced vary from city to city in developing countries, depending on several factors, with the most significant being population growth. For example, in 2016, according to the characterization by the National Waste Agency, Algeria produced nearly 12,000,000 tons per year, with a production growth rate of 3% (Figure 2).

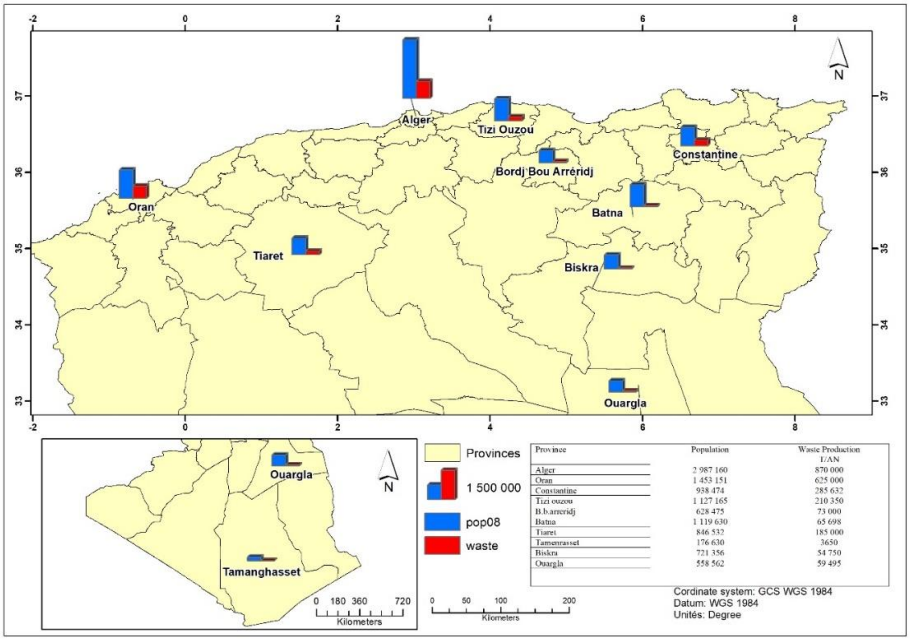


Fig. 2. Solid Waste Production in Algeria in Relation to Density (Source: AND, 2019; ONS, 2008)

It is important to note that the coastal cities of Algeria, which have a higher population density, generate significantly more waste compared to the High Plateaus and the South.

As for the Province of Algiers, it produced over 870,000 tons in 2016, followed by the Province of Oran with a production of 625,000 tons per year. Medium-sized cities produce between 200,000 and 300,000 tons of waste annually, such as Constantine in the East and Tizi Ouzou in the Center.

In fact, some cities produce less than 50,000 tons of waste per year. These are generally concentrated in the South, such as Biskra and Ouargla, and are characterized by low population densities, according to the RGHP of 2008. In the Grand South, the Province of Tamanrasset generates 3,650 tons of waste per year (figure 2). we observe that the further south we go, the lower the population density, and consequently, the waste production decreases.

The increase in Algeria's population, estimated at approximately 43 million in 2020, has a direct impact on waste production. At the regional level, coastal cities and major metropolitan areas generate more waste due to their high population density and intense economic activities (AND, 2020).

For example:

- Algiers produces over 1 million tons per year, with a ratio of 0.90 kg per capita per day.
- Oran, Sétif, Djelfa, and Blida record waste production ranging between 400,000 and 600,000 tons per year.
- Southern wilayas (e.g., Ouargla, Biskra, Laghouat) have lower waste production, generally below 300,000 tons per year, due to their low population density and limited industrial development.

Medium-sized cities such as Constantine and Tizi Ouzou produce between 200,000 and 300,000 tons of waste annually, while some southern cities like Biskra and Ouargla generate less than 50,000 tons per year (AND, 2020).

A waste characterization study conducted between 2018 and 2019 demonstrated that population growth mechanically leads to an increase in household and similar waste (DMA) production. For example, for a projected population of 4.14 million inhabitants in certain studied wilayas (Jijel, Constantine, M'sila, Ouargla) by 2024, DMA production is expected to exceed 1.2 million tons, equivalent to 290 kg per capita per year—a level comparable to the national average (AND, 2020).

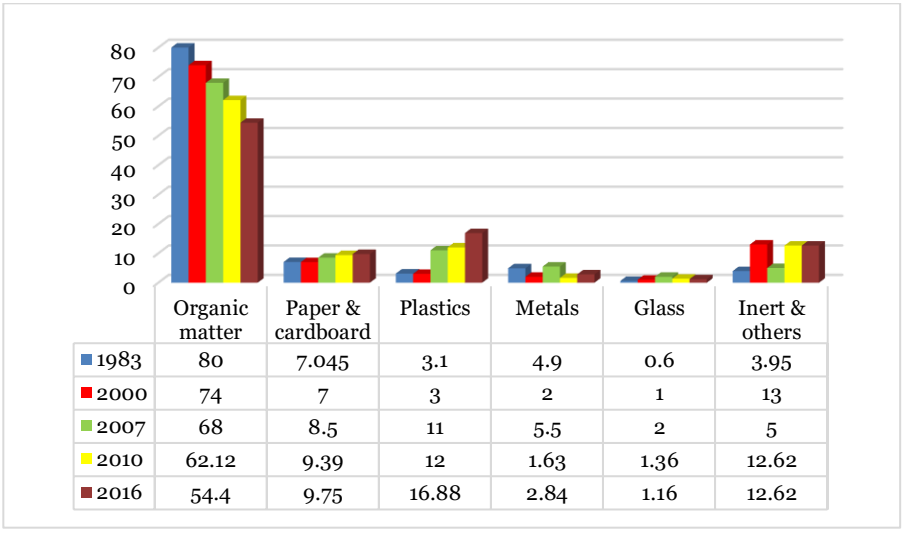
Solid Waste Management in Algeria

The coverage of household waste and similar waste collection is 85% in urban areas, while it is 60% in rural areas (Alg, 2014), In addition to this quantitative insufficiency, it should be noted that the mechanical equipment is no longer suitable for the task of collection, transportation, treatment, and landfilling of waste. The number of registered vehicles is 4,100, including 267 compaction trucks and 3,833 vehicles of various brands (Abdelli et al., 2017).

The immobilization rate of these vehicles is 50%. This is due to maintenance issues and a lack of management expertise. In addition to this major material constraint, there is also the issue of underqualification among waste management personnel. Out of a total national workforce of 20,000 agents, the qualification rate does not exceed 4% in medium-sized cities and ranges between 7% and 10% in large cities (Assia et al., 2024).

The Composition of Household and Similar Waste in Algeria

According to a 2014 study, the organic fraction accounts for 54.40% of household waste, which justifies biological recovery as a solution to reduce the quantities reaching landfills or technical burial centers in 2018, Algeria had 91 operational technical burial centers, 73 of which had reached a saturation rate exceeding 90%. The "National Strategy for Integrated Waste Management and Recovery by 2035" aims, among other objectives, to reduce household and similar waste by 10% by 2035 and to recover 47% of this waste (Bouadam, 2022).



	Organic matter	Paper & cardboard	Plastics	Metals	Glass	Inert & others
1983	80	7.045	3.1	4.9	0.6	3.95
2000	74	7	3	2	1	13
2007	68	8.5	11	5.5	2	5
2010	62.12	9.39	12	1.63	1.36	12.62
2016	54.4	9.75	16.88	2.84	1.16	12.62

Fig. 3. Evolution of the Composition of MSW (1983-2016) (unit: %) (Source: AND, 2019)

Between 1983 and 2016, the composition of household waste in Algeria changed significantly. Organic waste declined from 80% to 54.4% due to shifts in dietary habits and urbanization, while plastic waste surged from 3.1% to 16.88% due to increased packaging use. Paper and cardboard waste saw a slight rise, whereas metal and glass waste fluctuated with minor variations. The most notable increase was in inert and other waste, which grew from 3.95% to 12.62%, likely due to construction debris and non-recyclable materials. These trends highlight the need for improved waste management, recycling initiatives, and public awareness to promote sustainable waste reduction.

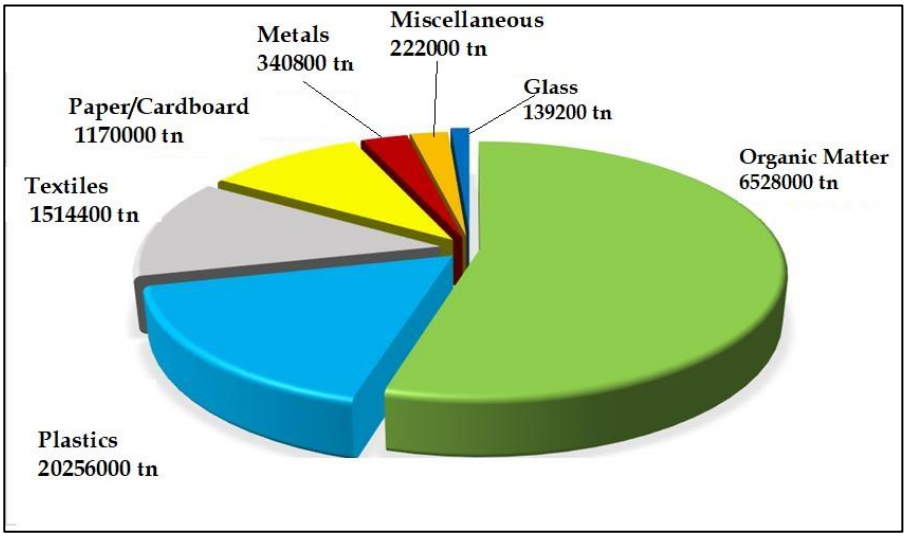


Fig. 4. Quantity of Waste by Type in 2016 (Source: AND, 2019)

The pie chart illustrates the composition of household and similar waste in Algeria, with organic waste being the most dominant at 6,528,000 tons, reflecting high consumption of fresh produce. Plastics follow at 2,025,600 tons, indicating widespread use of plastic packaging, while textiles contribute 1,514,400 tons, likely from discarded clothing and fabric waste. Paper and cardboard account for 1,170,000 tons, mainly from newspapers and packaging, whereas metals (340,800 tons) and glass (139,200 tons) represent smaller portions, originating from beverage containers and food packaging. Other waste makes up 282,000 tons, including miscellaneous or non-recyclable materials. These figures highlight the urgent need for improved waste management strategies, focusing on composting organic waste, promoting recycling, and reducing plastic use to mitigate environmental impact.

Means of Implementation for Solid Waste Treatment in Algeria

According to the Ministry of Environment and Water Resources, Algeria has the capacity to recover an estimated 760,000 tons of waste per year, representing 3.5 billion DA. Paper plays a crucial role in this recovery and recycling potential, with 385,000 tons collected annually, mainly through the system for retrieving unsold newspapers. Out of more than 2 million tons of plastic packaging produced by 192 units in Algeria, only 4,000 tons are recovered, representing a mere 0.0002% (Table 1).

Table 1. Waste Recovery Capacities and Percentage by Waste Type in 2016

Waste Type	Recovery Capacity	Percentage (%)
Paper	385,000 t/year	50.6
Plastic	130,000 t/year	17.1
Metals	100,000 t/year	13.15
Glass	50,000 t/year	6.57
Various Materials	95,000 t/year	12.5

Source: (AND, 2019)

For example, regarding paper waste, according to a publication by Tonic Emballage, a company specializing in packaging production in Algeria, the recycling capacity of the Algerian paper industry does not exceed 10% of the total waste generated annually. Meanwhile, national paper and cardboard consumption is estimated at 600,000 tons per year, with nearly 335,000 tons of waste being landfilled annually.

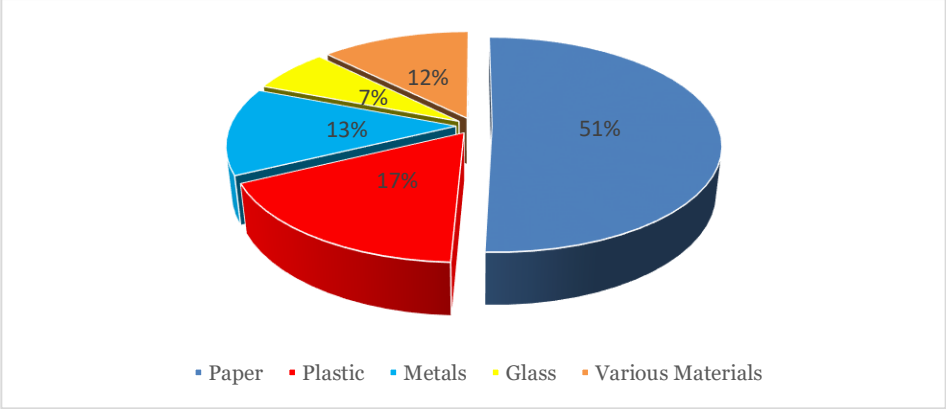


Fig. 5. Waste Recovery Capacities in Percentage (Source: AND, 2019)

Since 2002, Algeria has implemented a new policy focused on the recovery and valorization of packaging. This strategy aims to reduce packaging volume at the source and promote the use of biodegradable materials.

Packaging plays a crucial role in a company's product marketing process, with various types and materials available. Over the past decades, Algerian society has experienced significant changes in consumption habits, leading to a considerable increase in waste production, where packaging represents a substantial share rather than a negligible one.

The Ministry of Environment and Water Resources has established a public system for the collection and recovery of packaging waste under the label (Eco-Jem), which stems from the decree of November 11, 2002, related to the management of packaging waste[2], and the decree of July 19, 2004, related to the institutionalization of the national system for the collection and recovery of packaging waste[3].

Its main objective is to organize the sorting, collection, and treatment of packaging waste through service contracts. This aims at reducing the amount of waste produced, promoting recycling activities, conserving raw materials, and creating new jobs. This system is under the responsibility of the National Waste Agency. It represents one of the recommended solutions for packaging recovery in Algeria. The recovery of this volume of waste would amount to 3.5 billion dinars

Methods of Collection, Disposal, and Treatment of Waste in Algeria

Two stages are essential in waste management: removal and disposal. Waste removal includes pre-collection and the actual collection.

A - Pre-collection: The concept of pre-collection refers to all the operations that precede the actual collection of waste. It involves gathering, collecting, and storing waste by the residents of a household, building, neighborhood, or by the personnel of an organization or company, and then depositing it in designated waste collection areas. In Algeria, it takes various forms depending on the type of housing and the accessibility of facilities.

- Metal Containers: Pre-collection by container is more commonly used in local urban areas (ACL) and in secondary urban areas (AS). These are metal containers with a capacity of 2 to 2.7 tons, installed in neighborhoods, districts, and in front of establishments that generate large amounts of waste. The frequency of collection from these containers ranges from two to three times a week.

- Concrete Niches: These are designed as structures surrounded by a masonry wall enclosing a solid base. The wall has an opening allowing users to deposit waste and for waste

[2] Executive Decree No. 02-372 of 6th Ramadan 1423, corresponding to November 11, 2002, related to packaging waste. (OFFICIAL JOURNAL OF THE ALGERIAN DEMOCRATIC AND POPULAR REPUBLIC No. 74, 2002)

[3] Executive Decree No. 04-199 of 1st Jumada al-Thani 1425, corresponding to July 19, 2004, establishing the procedures for the creation, organization, operation, and financing of the public system for the treatment of packaging waste. (OFFICIAL JOURNAL OF THE ALGERIAN DEMOCRATIC AND POPULAR REPUBLIC No. 46, 2004)

collectors to remove it. These niches are usually installed in villages without prior studies, without protection against animals, and without measures to treat leachate.

- Individual Bins: These are individual plastic bins, and this mode of pre-collection is widely used by residents in city centers and by shopkeepers. The waste is placed in these bins, which, once emptied by the collection service, are returned to the residents.

- Disposable Plastic Bags: This type of pre-collection is the most widespread in city centers and in individual housing neighborhoods. Before the collection trucks arrive, shopkeepers and residents of neighborhoods place their waste in plastic bags or cardboard boxes in front of their homes or on the sidewalks, in the form of piles that the municipal collection truck picks up and transports to the municipal landfill.

- Rolling Bins: This mode of pre-collection is mainly applied in pilot cities that are part of the PROGDEM program. Bins ranging from 120 to 1,100 liters are placed in neighborhoods for a group of households to replace the old metal container system. These bins are necessary for collection by compactor trucks.

B - Waste Collection: The collection operation is at the heart of the waste management process. It is a public service operation aimed at protecting the health of populations and ensuring a better quality of life. It involves the gathering and grouping of waste for transportation. Currently, there are two methods of waste removal in Algeria:

- Door-to-door service, in which the collection service ensures regular passes for the evacuation of Municipal Solid Waste (MSW).

- Voluntary drop-off, in which the generator ensures the transfer of Household Waste (HW) to a collection point so that it can be transported by the service responsible for the operation to a disposal or treatment site. This method is well-suited for selective sorting operations. Waste collection is organized by municipalities according to their size.

- Selective collection involves separately collecting one or more categories of waste, such as glass, paper and cardboard, and scrap metal, which are already well known to the public. The separate collection of "green waste," consisting mainly of kitchen or garden waste containing only organic residues, is practical in certain regions.

Types of Collection and Transport Vehicles in Algeria

In Algeria, waste collection and transportation are managed using various types of vehicles tailored to urban and rural settings. Recent data provides insight into the prevalence and distribution of these vehicles across the country.

Collection Trucks with Closed Body and Waste Compression: These vehicles are predominant in urban areas of Algeria. For instance, in Constantine, the municipal waste management fleet comprises 53 compactor trucks, which are responsible for collecting approximately 257 tons of household waste daily. This fleet is supported by a dedicated team of 540 staff members (Area, 2018).

Agricultural Tractors with Dump Trailers: In rural regions, agricultural tractors equipped with dump trailers are commonly used for waste collection, especially from agricultural and livestock activities. While specific national statistics are limited, the reliance on such equipment is evident in rural waste management practices. A 2016 report high-

lighted that the Ministry of Environment acquired 225 new waste containers for Constantine as part of its Program for the Mechanization of MSW Management, aiming to enhance waste collection efficiency in both urban and rural areas (Kouloughli & Kanfoud, 2017).

Planning and Organization of Collection

The collection of household and similar waste is generally managed by a door-to-door service, provided either by the municipality or a specialized company, which also determines the days and frequency of collection.

For the planning and organization of waste collection, detailed plans of all the neighborhoods to be served must be available, including the length and width of streets, traffic flow direction, urban structure, the number of inhabitants, and the locations of markets, shops, administrative buildings, factories, and other significant waste production points.

After analyzing the data, the quantities of waste per point and street section can be calculated, allowing for the determination of the number, capacity, and distribution of containers to be used. Based on the estimated waste volumes for each collection type, whether door-to-door or voluntary drop-off, the necessary containers are specified, including individual or communal household bins ranging from 120 to 1100 liters, as well as bins for recyclable waste, and separate containers for glass, plastic, paper, and cardboard.

Taking all of this data into account, in a second phase, a plan can be drawn for each neighborhood indicating the collection routes. There are also computer programs that, after inputting the data reviewed above and the capacities of the collection trucks, indicate the optimal collection routes. Still aiming for optimization, the established routes must be adaptable based on urban planning factors, such as the construction of a building or a commercial establishment.

Waste Disposal

After presenting the different waste collection methods in Algeria, we will now discuss the two main approaches to waste disposal and treatment. Among the techniques used, recycling stands out, which involves processing and reintroducing materials from waste back into the production cycle to reduce their volume and preserve natural resources. Incineration, on the other hand, involves the combustion of waste to reduce it to ash, making it a common waste management method. Finally, composting, which is increasingly favored due to concerns about landfills, transforms organic matter into a stable and enriching product for soils, with industrial-scale applications in several countries.

In general, disposal remains the solution applied to 82% of the waste produced in Algeria. Waste intended for disposal is sent to open dumps in 46% of cases and to controlled landfills (CET) in 36%. Only 11% of waste is valorized, with 10% being recycled and 1% composted. However, waste valorization or recycling is a more suitable approach that results in the reduction of waste. It can be considered a preferable solution compared to landfill disposal.

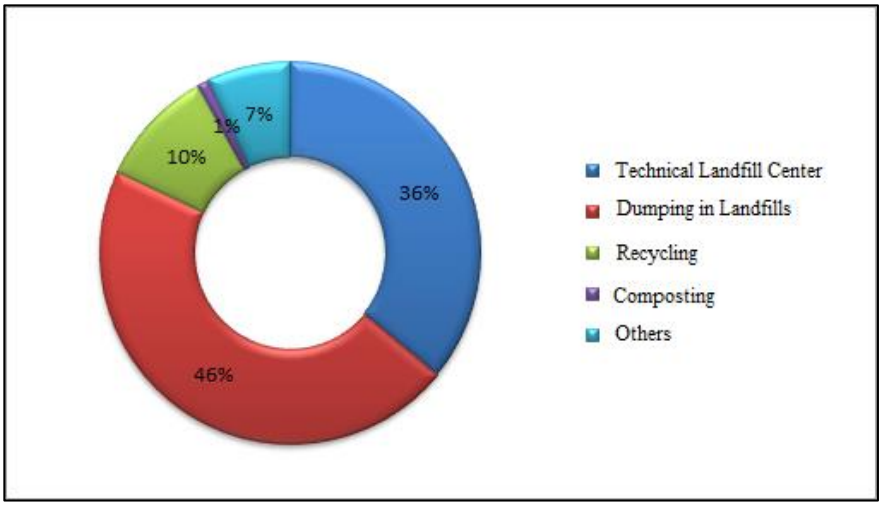


Fig. 6. Waste Treatment Types (Source: AND, 2019)

Waste Storage Centers

"Everyone has an idea of what a landfill represents, as every society has always needed, to dispose of its waste, a means or a place serving as a 'dump'. Those more familiar with the topic know that the habits of our ancestors—discarding their trash, and more generally all waste, without any precautions, in the first hole they found—have greatly changed in recent decades" (Kibert, 2016).

The controlled landfill is one of the recommended waste management methods, but it presents risks of contamination for surface water and groundwater, which could be used for drinking water disposal. Over time, the landfill has transformed into a Technical Landfill Center, with rules that include the recovery of gaseous (biogas) and aqueous (leachate) effluents, the selection of admissible waste, and the monitoring and control of operations.

To further protect the soil and subsurface, safety and protection barriers have been implemented, acting as screens to minimize environmental impacts. The conditions for installation, development, operation, and monitoring are mandated due to the numerous risks that could affect human health and the environment.

Technical Landfill Center

According to Article 2 of the Walloon Decree of June 27, 1996, relating to waste, Technical Landfill Centers (TLCs) refer to sites intended for the disposal of waste by depositing it on or in the ground, including underground. These sites include internal landfills, where the producer manages waste disposal at the production site, as well as permanent sites used for the temporary storage of waste for a period exceeding one year. However, installations where waste is simply unloaded for preparation before transport for recovery, treatment, or disposal elsewhere, as well as the storage of waste for less than three years before recovery or treatment, or less than one year before disposal, are not considered TLCs.

Depending on the nature of the accepted waste and its permeability, waste storage centers are divided into three classes.

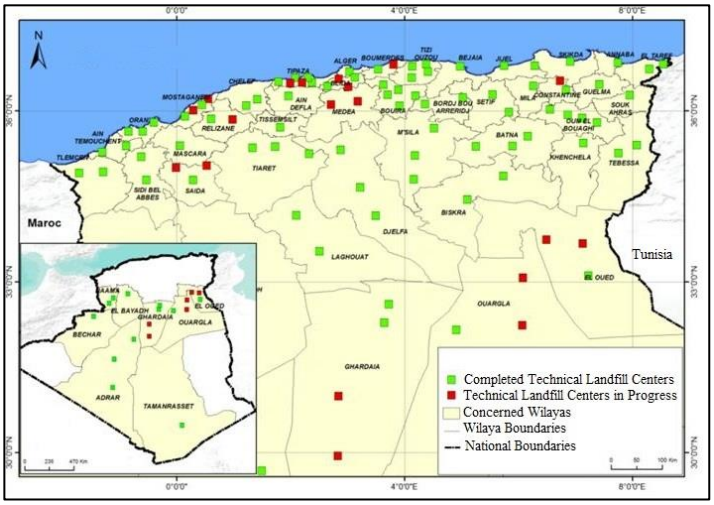


Fig. 7. Location of completed and ongoing TLCs in Algeria (Source: AND, 2019)

According to figure 7, which summarize the location of ongoing and completed Technical Landfill Centers (TLCs) in Algeria:

Firstly, we notice that most of the completed and ongoing TLCs are concentrated in the northern part of the country due to the high waste production rate recorded in this region. Secondly, we observe that the number of completed TLCs is significant and distributed according to the waste production rates in the internal regions.

Finally, regarding the South, which occupies the largest area of the country with a scattered and dispersed population, we see that it has the lowest waste production rates. This implies that establishing multiple TLCs in this region is unnecessary.

Following the launch of the PROGDEM program, 65 TLCs were recorded during the period from 2001 to 2005, with 16 completed, 28 under construction, and 21 in the study phase. By the end of 2007, this number increased due to the results of pilot projects, particularly the one in Oueld Fayet, Algiers, reaching 80 projects, with 20 completed, 34 under construction, and 26 in the study phase, representing 15 new projects. The provinces concerned include Skikda, El-Taref, Annaba, Guelma, Souk Ahras, Batna, Tébessa, Média, Tizi-Ouzou, Sétif, Biskra, Algiers, M'Sila, Ouargla, Blida, Djelfa, Jijel, Béjaia, and Chelf. By 2017, this number had increased to 202 TLCs, the majority of which were almost completed, with 152 TLCs finished, 30 under construction, and 20 in the study phase.

Possible intervention measures within the framework of an environmental protection strategy

We observe that 20 Technical Landfill Centers (TLCs) are in the planning phase, with the majority located along the coast, particularly in Blida, Boumerdès, Médéa, and M'Sila in the central region. Additionally, five TLCs are planned for the West, distributed as follows: 3 in Chlef, 1 in Mostaganem, and 1 in Mascara. In the South, 5 TLCs are planned for Ouargla, 1 in Oued, and 2 in Naama.

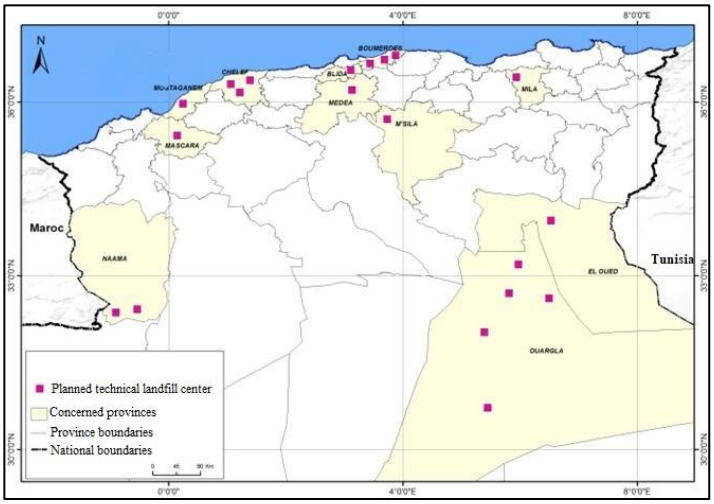


Fig. 8. Location of Planned Technical Landfill Centers in Algeria (Source: AND, 2019)

Finally, we conclude that Algeria has more Technical Landfill Centers (TLCs) in the North, which is a result of the higher population density in the North compared to the South.

Rehabilitation of Waste Disposal Sites: Rehabilitation of seven of the largest landfills in the country to improve the living conditions of citizens and recover usable land.

Rehabilitation of the Oued Smar Landfill: As an example, we can mention the Oued Smar landfill, which was closed in September 2014. In its place, a 204-hectare public garden was created, which has since become a recreational area for the residents of the capital.

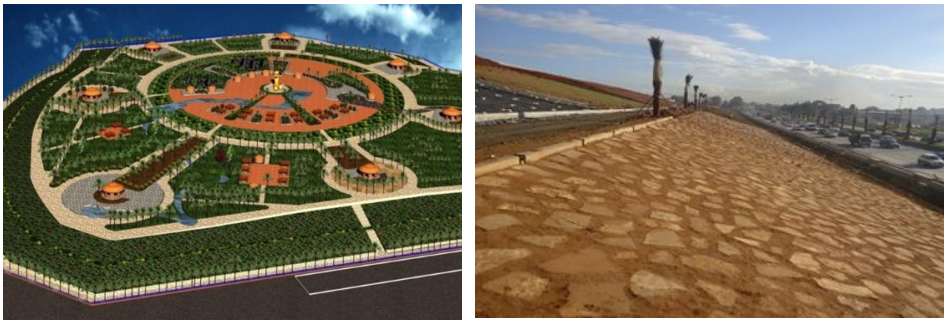
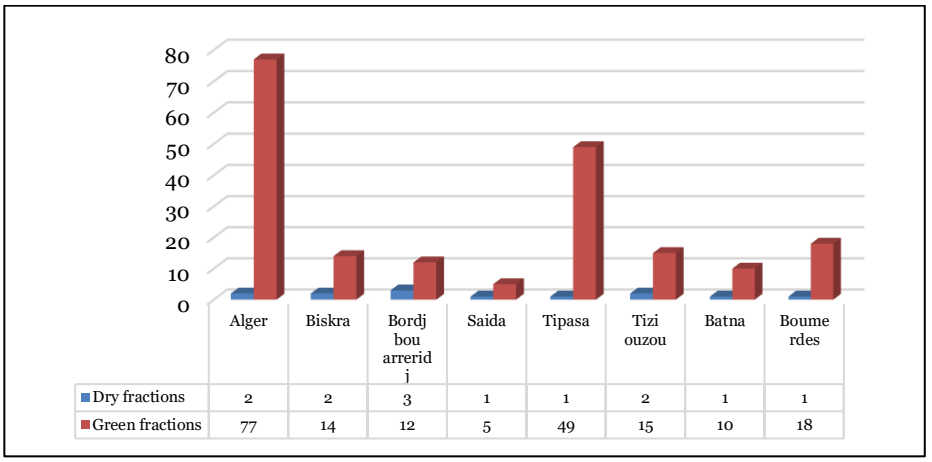


Fig. 8. Rehabilitation of the Oued Smar Landfill (Source: AND, 2020)

A demonstration project for the benefit of local authorities, initiated by the Ministry of Environment and implemented by AND. It involves gradually introducing selective household waste collection in Algeria through pilot operations in several neighborhoods per province. This collection is carried out through multi-material sorting into two fractions: dry and wet:

- Yellow bin: intended for receiving recyclable dry waste (cardboard/paper, plastic, metal/aluminum)
- Green bin: intended for receiving other waste (fruit and vegetable peels, soiled cardboard packaging, or any other waste).

The objectives of the project are as follows: encourage local authorities to adopt integrated waste management in their territories, raise public awareness about the importance of selective sorting and its impact, improve the recovery and recycling rates of recyclable waste, and promote the development of the circular economy.



	Alger	Biskra	Bordj bou arrerid j	Saida	Tipasa	Tizi ouzou	Batna	Boume rdes
Dry fractions	2	2	3	1	1	2	1	1
Green fractions	77	14	12	5	49	15	10	18

Fig. 9. Number of bins per neighborhood by Province (Source: AND, 2020)

The table presents the allocation of bins for waste collection in various neighborhoods across different Provinces in Algeria, categorized into dry fractions (recyclables) and green fractions (organic waste). Notably, Algiers has the highest number of bins, with 77 for dry fractions and 225 for green fractions. Biskra follows with fewer bins, 14 for dry fractions and 40 for green fractions, while Bordj Bou Arreridj has 12 for dry fractions and 32 for green fractions. Saida shows a relatively low number of bins, with 5 for dry fractions and 28 for green fractions. In Tipasa, the allocation is fairly balanced with 49 bins for dry fractions and 52 for green fractions. Tizi Ouzou has 15 bins for dry fractions and 53 for green fractions, indicating a similar focus on both types of waste. Batna has 10 bins for dry fractions and 42 for green fractions, while Boumerdes features 18 bins for dry fractions and 48 for green fractions. This distribution highlights the varying levels of resources dedicated to waste management across different regions, with a stronger emphasis on managing organic waste in some areas.

Fig. 10. Prototype of a clean neighborhood

Pilot Compost Production Unit

The pilot compost production project is currently being implemented at the Hassi Bounif Technical Landfill Center (CET). It is based on the valorization of organic waste from the wholesale fruit and vegetable market in El Kerma, in the Province of Oran, as well as green waste from tree pruning in the municipalities of Oran and Bir El Djir. The goal is to use these waste materials to produce high-quality compost, thus contributing to the reduction of organic waste and its transformation into a valuable soil amendment for agricultural lands and green spaces.

This project is divided into three main phases. The first phase involved selecting a composting technology known as "in-vessel," which uses containers equipped with devices that allow for precise control over the environmental conditions of decomposition. This method ensures the compost is free of pathogens, accelerates its maturation time, and improves its overall quality. Moreover, it allows for the easy duplication or relocation of this type of project to other similar sites.

Fig. 11. Pilot Compost Production Unit (Source: Benkrama & Beladjine, 2016)

The second phase focused on acquiring the necessary equipment, including two containers and a compost turner, intended for the implementation of the project at the Hassi Bounif CET. These pieces of equipment were transferred to the EPIC CET to ensure their operation. The third phase, currently ongoing, aims to monitor and evaluate the aerobic composting process, without using the container. In this context, windrows have been formed and are being monitored by the expertise of Compost Systems, which oversees the waste degradation process. At this stage, 5 tons of waste are being processed, with a nine-week monitoring period required to obtain mature compost ready for sieving and use in agriculture. The first batch of compost produced has already been used for the green spaces at the Hassi Bounif CET. The next phase, scheduled for the first quarter, will involve using the containers for compost production, with a capacity of 10 tons of raw waste per week.

In parallel, awareness and training actions have been established to support the project's implementation. Information sessions on waste management, selective sorting, and composting were organized for the technical staff of the El Kerma wholesale fruit and vegetable market. These staff members, as the primary suppliers of organic waste, play a central role in the project's success. A second training and awareness session was also conducted for the market representatives to further involve them in this initiative. Additionally,

initiatives were undertaken with the Directorate of Environmental Protection (DPE) of the Oran APC, the Bir El Djir APC, and the Forest Conservation of Oran Province to ensure a regular supply of green waste.

In addition to this composting project, a recycling program has been launched to structure waste management and promote the circular economy. This program aims to create 247 micro-enterprises specializing in waste recovery, as well as 25 recycling units. These units are distributed as follows: 17 for plastic and rubber recycling, 2 for packaging, and 6 for other types of waste. A market study is underway to organize and develop new waste valorization channels. This study includes an inventory and quantification of waste, particularly paper and cardboard, liquid effluents, and sewage sludge. For each channel, a specific program will be proposed, covering the stages of collection, aggregation, and recycling of waste to optimize its valorization.

Conclusion

Urban waste management in Algeria remains one of the serious challenges to environmental protection and public health. The expanding flow of waste, primarily due to population and patterned consumption changes, contributes to the difficulty of managing waste, treatment, and recycling. Despite efforts and measures taken towards maximizing waste management, collection coverage remains inadequate, particularly in rural areas.

The recent trend (2019-2023) analysis indicates that there is real decrease in the production of household and analoguous waste (DMA) post-COVID-19 pandemic because of the change in behavior. But waste composition has become diversified with unprecedented increase of plastic waste, though organic waste remains the largest percentage. Waste recycling initiatives are being formulated, particularly with the launch of pilot initiatives such as composting in Hassi Bounif's Technical Landfill Center (CET) and packaging waste management optimization. Nevertheless, much of the waste remains poorly managed, either entombed in CETs with over-capacity or illegally dumped, posing critical environmental hazards.

Developing the collection infrastructure, enhancing the capacities of sector players, and stepping up sensitization campaigns are therefore imperative to enable selective sorting and source reduction. The use of circular economy policies and new technologies such as composting and recycling represent main strategic drivers of sustainable waste management in Algeria.

Conflicts of Interest: The authors declare no conflict of interest.

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